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MEASUREMENT OF IONOSPHERE TEMPERATURE STARTING FROM
THE VIBRATION SPECTRUM OF THE TRANSITION
 $X^2\Sigma^+ \rightarrow A^2\Sigma^+$ OF THE AlO MOLECULE

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THE VIBRATION SPECTRUM OF THE TRANSITION
 $X^2\Sigma^+ \rightarrow A^2\Sigma^+$ OF THE AlO MOLECULE *

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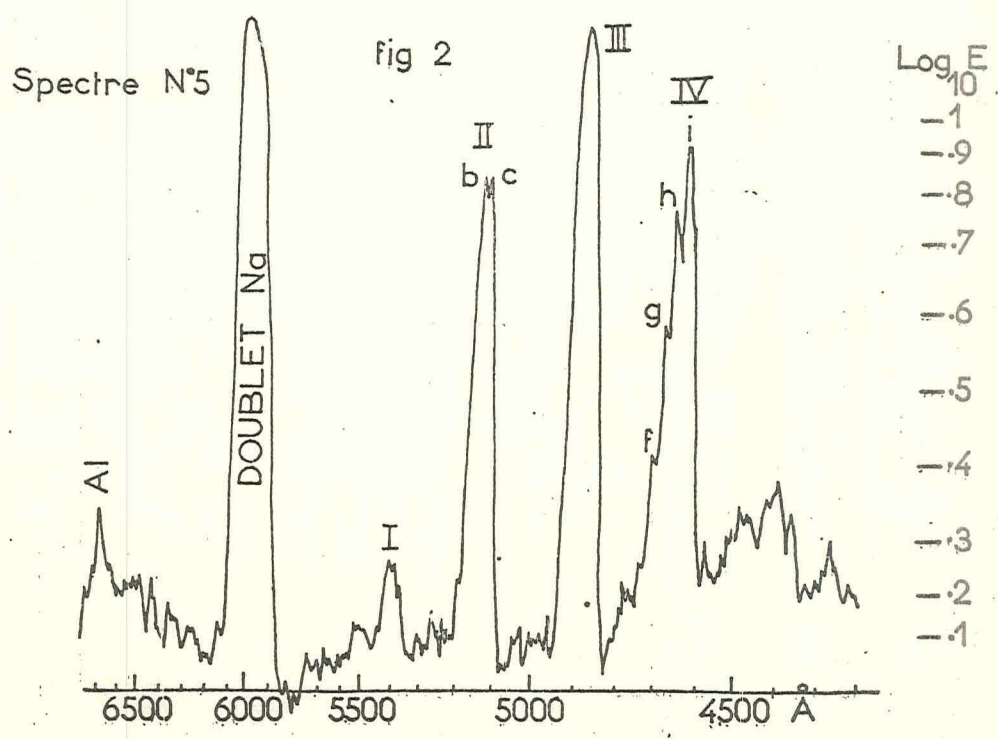
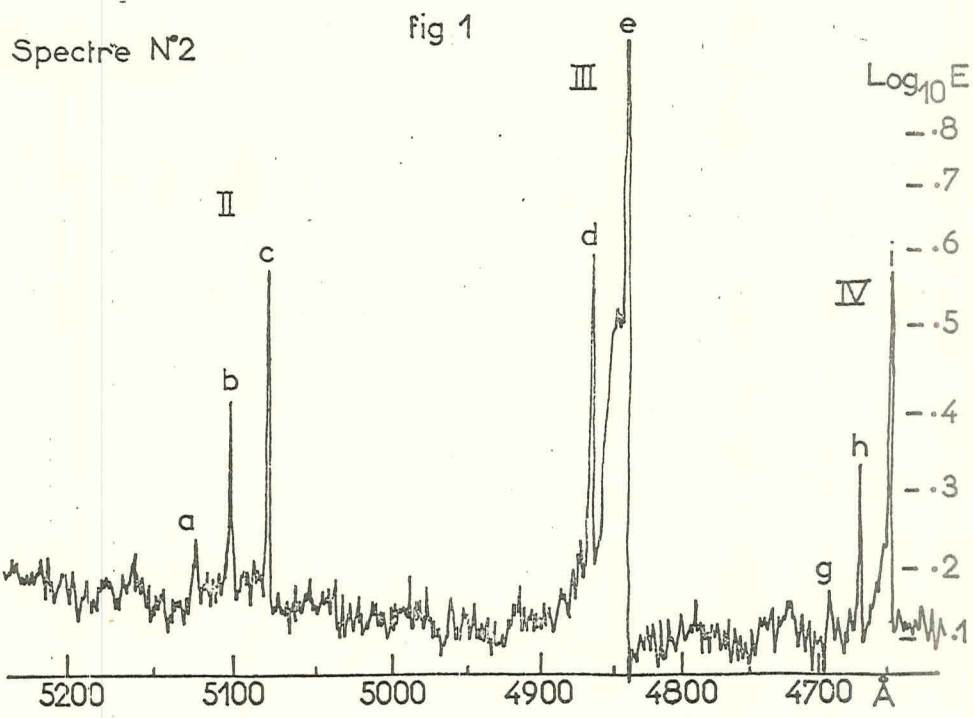
We have described in a preceding Note an experiment concerned with the explosion of a charge of 58 kg of exogenous tolit at 170 km altitude at twilight of 24 May 1962 [1]**.

Aside from the three spectra obtained with the aid of a REOSC spectrograph (Fig.1), which served to determine the temperature of the AlO -cloud formed [1], we took the following five exploitable spectra (Fig.2) on a Kodak plate 103 AF by means of a SGO - spectrograph with glass prism (f/0.7):

Spectrum	Beginn.of exp.	End of Exposure
5	H + 1 m 30 s	H + 2 m 30 s
6	2 30	3 30
7	3. 30	4 30
8	4 30	5 30
9	5 30	6 30

These five spectra, as well as the preceding three, calibrated photometrically with a Barbier wedge and spotted in wavelength, allow the study of the vibration spectrum of the transition $X^2\Sigma^+ \rightarrow A^2\Sigma^+$ of the molecule AlO .

* Mesure de la température de l'ionosphère a partir du spectre de vibration de la transition $X^2\Sigma^+ \rightarrow A^2\Sigma^+$ de la molécule AlO .
 [Note présentée par M. Jean Coulomb]



We recognize in Fig. 2, near the atomic lines of Al [I] at 6696 Å and Na [I] at 5893 Å, and of the sequence $\Delta v = -2$ of AlO at 56360 Å of little intensity, the following sequences appearing in both spectra:

II.			III.			IV.		
$v' - v''$		λ	$v' - v''$		λ	$v' - v''$		λ
$\Delta v = -1$	$a : 2-3$	5123	$\Delta v = 0$	$d : 1-1$	4866	$\Delta v = +1$	$f : 4-3$	4716
	$b : 1-2$	5102		$e : 0-0$	4842		$g : 3-2$	4698
	$c : 0-1$	5079					$h : 2-1$	4672
							$i : 1-0$	4648

Theoretical Aspect of the Method. - When the fluorescence of a molecule is excited by solar light, the luminous intensity of an excited band ($v' v''$), of average frequency $\nu_{(v', v'')}$ is expressed by

$$I_{(v', v'')} \propto \frac{h \nu_{(v', v'')} g(v') P_{(v', v'')} \nu_{(v', v'')}^2}{\sum_{v''} P_{(v', v'')} \nu_{(v', v'')}^2},$$

$g(v')$ is the rate of population of levels v' which depends on Franck-Condon factors $P_{(v', v'')}$, on the distribution $N(v'')$ of molecules in the vibration levels of the fundamental state and on the exciting solar radiation $\odot_{(v'', v')}$, only cause of excitation since the observed cloud disappears from the moment it enters the Earth's shadow:

$$g(v') \propto \sum_{v''} N(v'') \frac{P_{(v', v'')}}{\nu_{(v', v'')}} \odot_{(v'', v')}.$$

$N(v'')$ obeys the Boltzmann law, provided the average time separating two fluorescence processes for one molecule is sufficient for its reaching the state of equilibrium with the medium. The study of cloud's brilliance and conditions of AlO formation (which appears during the first two seconds following the explosion) shows that this average time is ranging between 2 and 10 sec (20 to 200 impacts) which is sufficient for reaching the thermal equilibrium. If the excited state $A^2\Sigma^+$ is not populated by a transition stemming from a superior electronic state — namely the transition $B\Sigma \rightarrow A^2\Sigma^+$

observable between 7900 and 8700 Å (W. M. Goodlett [3] refers to it as being 20 times less intense than the transition $X^1\Sigma^+ \rightarrow A^1\Sigma^+$), and if, on the other hand, the molecules have no time to change the vibration level in the excited state, which does not take place indeed, for the lifetime of the excited state (10^{-8} to 10^{-7} sec) is too short, $g(v')$ will be given by the equation (2).

Under these conditions the intensity ratio of two, or of one set of lines of same rotation index, pertaining to two different bands, will only depend on temperature.

Our spectrographs' separating power (1.5 Å for the REOSC and 10 Å for the SGO) allows the comparison of only band heads' intensity. In order that such comparison make sense, it is necessary that the band head "composition" for the same resolution be identical, i.e. that the index m_{\max} of the retrogression line, just as the distance Δv separating the center of the band head, be practically constant. This condition is fulfilled for a sequence as the examination of the Fortrat parabola indicates. We shall therefore compare the band head intensities belonging to the same sequence. The study of the Condon parabola in the Deslandres diagram indicates that the sequences $\Delta v = +1$ and $\Delta v = -1$ are best adapted for that comparison. These sequences' bands offer the advantage of not overlapping. We shall thus compute the populations of the vibration levels of the fundamental state, of the excited state, and then the intensities of the fluorescence bands of the sequences $\Delta v = +1$ and $\Delta v = -1$, which we shall compare with those corresponding to our spectra.

Calculation of Band Head Intensities of the Sequences

$$\underline{\Delta v = +1 \quad \text{and} \quad \Delta v = -1}$$

The population $N(v'')$ of a level v'' of the fundamental state ratio to the level $v'' = 0$ of that state is computed by applying the Boltzmann law:

../..

$$\frac{N(v'')}{N_0} = e^{\frac{-[G(v'') - G_0]hc}{kT}},$$

where $G(v'')$ is the end point of vibration energy of the level v'' .

The population's $g(v')$ rate of a level v' of the excited level $A^2\Sigma^+$ is given by the equation (2) where the Franck-Condon factors $p(v'', v')$ are known [4], just as is the mean exciter solar intensity $\Phi_{(v'', v')}$ given by Chalonge [5]. A great number of lines contribute to the intensity of a band head and the examination of the "Atlas d'Utrecht", just as the coincidence of the results obtained with our two spectrographs of different resolutions, authorize us to neglect the effect of Fraunhofer lines.

We then may compute the total fluorescence intensity of a band after (1). By bringing to 100 the intensity of the bands 1-0 and 0-1, we have computed the relative intensities of the different bands of the sequences $\Delta v = +1$ and $\Delta v = -1$ for various temperatures :

$\Delta v = +1.$					$\Delta v = -1.$				
$v' - v''$	600°K.	700°K.	800°K.	900°K.	$v' - v''$	600°K.	700°K.	800°K.	900°K.
1-0.....	100	100	100	100	0-1.....	100	100	100	100
2-1.....	35,4	39,8	43,8	48,5	1-2.....	49	50,4	54,4	56,4
3-2.....	8,0	10,4	12,9	15,6	2-3.....	14,4	16,8	19,7	22,2
4-3.....	0,2	0,56	0,98	1,59					

In this temperature range, the sequence $\Delta v = +1$ offer the greatest intensity variations with temperature; we shall thus select it for our measurements, the sequence $\Delta v = -1$ not permitting to check the method. The studied band heads having the same composition, their intensity is a constant fraction of the total intensity of the band.

Measurements. — The band heads' intensity ratio i and h gives one temperature; our spectra allow us above all to compare i and g and also i and f . We thus have three possible measurements for the same spectrum.

The aggregate of our spectra gives a mean temperature of $750 \pm 150^\circ \text{K}$ without systematic deviations of importance, function of the spectrograph or of the band heads compared. The first spectrum taken in the explosion, gives a higher temperature (950°K). The study of the rotation spectrum provided us with a result quite close.

**** THE END ****

Translated by ANDRE L. BRICHANT
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REFERENCES

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[2]
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